R&T UPDATE
Concrete Pavement Research & Technology

AIR CONTENT IN CONCRETE PAVEMENTS

Entrained air is necessary in hardened concrete for freeze-thaw resistance when exposed to cold temperatures, water, and deicing chemicals. Entrained air also secondarily benefits both freshly mixed and hardened concrete by improving workability, sulfate resistance, and alkali-silica reactivity (ASR) resistance. Entraining air in concrete can be accomplished by adding an air-entraining admixture, by using an air-entraining cement, or by a combination of these methods. For pavement concrete, entrained air is typically introduced into concrete through an air-entraining admixture.

Contracting agencies normally specify a minimum air content for concrete paving mixtures, assuming this will result in the necessary amount of entrained air for free-thaw resistance. However, the key to a durable concrete pavement is in the air bubble size and spacing, not necessarily the air content. It is important to be aware that the air content changes as the concrete is transported from the concrete plant to the paver and also through the paver. A specifier must decide how much air or loss of air is acceptable, and the contractor must understand the implications in terms of yield loss and strength.

Traditional Measurement of Air Content

Air content in fresh concrete is commonly measured in the field using either the pressure method (ASTM C 231 or AASHTO T 152) or the volumetric method (ASTM C 173 or AASHTO T 196). The pressure method (Figure 1) is practical for field-testing most concretes except those made with highly porous and lightweight aggregates. The volumetric method (Figure 2), also called the roll-a-meter, is practical for field-testing all concretes, including those with lightweight and porous aggregates. However, neither method is capable of accurately measuring air content of concrete made with synthetic air-entraining agents, which produce small bubbles of high surface tension.

Figure 1. Traditional apparatus for measuring air content using the pressure method.

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Figure 2. Traditional apparatus for measuring air content using the volumetric method (roll-a-meter).

In addition, the pressure method and the volumetric method have three other major deficiencies. First, the methods yield total air content in concrete (entrained and entrapped air) rather than only the entrained air, which is what affects the durability of hardened concrete. Second, the methods give neither the size of air-entrained bubbles nor information on the spacing of bubbles. To determine the size and spacing of bubbles, the hardened concrete sample must be polished and tested by a petrographer according to ASTM C 457, *Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete*. The results of this test are neither timely nor inexpensive. Thirdly, the pressure and volumetric methods measure the air content in the concrete before it has passed through the paver and undergone vibration and consolidation, further limiting their ability to accurately represent the concrete's durability.

These shortcomings limit the existing procedures' usefulness in the field for quality control and quality assurance plans and specifications, particularly those aimed at long-term durability.

The Air Void Analyzer

In the early 1990s, researchers in Europe developed a new technology to characterize the air-void system of the fresh concrete. The system, known as the Air Void Analyzer (AVA), has the capability of measuring the air content, specific surface, and spacing factor in fresh concrete. The test results compare favorably with ASTM C 457.

The AVA specimen collection device consists of a high-speed drill, used to vibrate the cage that collects the concrete sample, a 20 mL syringe, and a plastic template. The drill is turned on, vibrating the cage, and it is slowly pushed through the opening in the template (Figure 3). The concrete mortar fills the cage, and then the syringe is extended to capture a sample of the mortar (Figure 4). Samples are easily obtained in less than five minutes.

Figure 3. Apparatus for obtaining concrete sample for Air Void Analyzer.

Figure 4. Obtaining concrete sample for Air Void Analyzer.

The AVA uses the sample of fresh concrete and analyzes the entrained air bubbles that it contains. This is done by mixing the sample with a glycerin solution which releases the entrained air bubbles from the mortar (Figures 5 & 6). Their volume is measured by weight and their size is calculated. An algorithm is then used to convert these two values into an air-void spacing factor. This information can be used to adjust dosages and types of both the air-entraining agent and the water reducer to obtain a better spacing factor in real time.

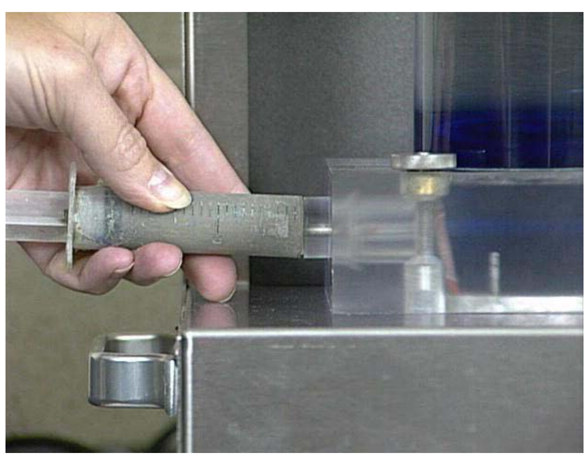

Figure 5. Attaching syringe filled with concrete sample to AVA apparatus.

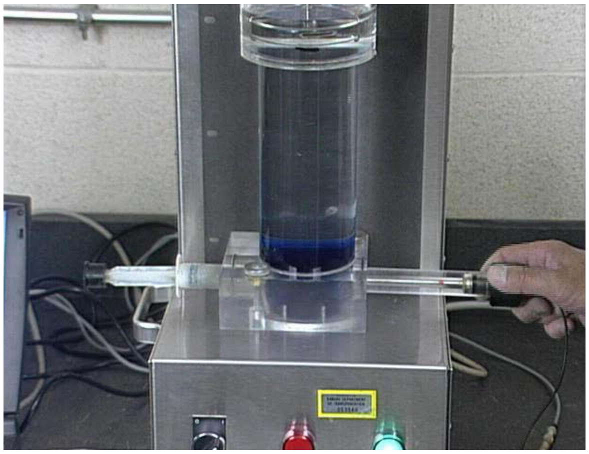

Figure 6. Inserting concrete sample into AVA apparatus.

The European AVA technology was first evaluated by the FHWA, and later by the state of Kansas. The field trials in the U.S. show that the AVA and C 457 data correlate well, except for total air content. The evaluation showed that the two methods give about the same spacing factor, which is generally regarded as the most significant indicator of the durability of the cement paste to freezing and thawing.

Improving the Air-Void Spacing Factor

If a concrete paving project demonstrates a poor air void structure yet still has the specified total amount of air, the following techniques can be used to improve the air-void spacing factor. However, these strategies should be evaluated prior to a blanket change in the concrete mixture, to determine their cost-effectiveness.

- Maintain a higher air content
- Increase the slump
- Use a more well-graded coarse and fine aggregate mixture
- Increase the mixing time, up to 150 seconds maximum
- Change types or brands of water reducer, air entraining agent, or both
- Modify the plant configuration, i.e. introduce aggregates together on the belt feed (multiple weigh hoppers), dual drums, etc.

The Kansas Department of Transportation (KDOT) currently has a specification for the use of the Air Void Analyzer. The specification sets a minimum air content of 5% and a maximum spacing factor of 0.25 mm (10 mils). KDOT researchers found that concrete paving projects where the spacing factor was greater than 0.25 mm (10 mils) had freeze-thaw durability problems, particularly where wet, saturated concrete underwent freeze-thaw cycles.

Because the new AVA technology, with a testing time of 25 minutes, can be used on fresh concrete, the system can be employed successfully for the quality control and evaluation of concrete on a real time basis. For more information about the Air Void Analyzer, contact John Wojakowski, Kansas DOT, at (785) 296-7410 or johnw@ksdot.org.

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